MAE 250F, Hypersonic and High-Temperature Gas Dynamics

Final Project

Due at Student Project Presentation: Monday, March 15, 2010, 3:00 pm - 6:00 pm, In the Lecture Room

The suggested topics of the final projects are given below. If you choose your own topic, it has to be related to the knowledge learned in the class, i.e., hypersonic flow applications. Please hand in a sheet of paper with your preferred project topic in the class on Wednesday, February 23, 2010.

You are required to hand in a written final project report. In your final report, you need to present the following main aspects:

1. Title page with title, you name, date, etc.
2. Introduction and description of the technical problem
3. Governing equations
4. Descriptions of your approach, methods, equations, etc.
5. Input data and parameters
6. Computations results presented in figures
7. Discussions of results
8. Conclusions
9. References cited in the report
10. A print out of your computer program.

We will hold a final project presentation in the time slot of the final exam for the class. Each student has five minutes to present his work or the lessons learned in the project. Because it takes time to upload all 29 presentations, one by one, in my computer, you are required to come to my office between 1 pm to 1:30 pm on the day of the presentation to hand in the following items to me:

1. A paper copy of your final project report;
2. A flash memory stick with the following electronic files to be uploaded to my laptop:
   - Your final report in MS Words or pdf formats.
   - The references used in your project in PDF format.
   - Your computer source codes, results, and figures for the final project.
   - Your power-point file for your five minute presentation.
   - For easy identification among the 29 students in the presentations, please put all your material in a single folder with the following standard naming convention: "Lastname-FirstInitial-Project." For example, my folder should be named as: "Zhong-X-Project". I will simple copy that folder of yours in one place.

Suggested Topics

Please note that each project is a guideline of a general problem, which is an independent research with no closed form solutions. It is up to you to decide how to do it. As for all research, you need to first do a literature search and read some relevant publications. Most of the papers are cited in the books of Anderson or Vincenti. You can also search papers through google or in the NASA technical reports server at http://ntrs.nasa.gov/search.jsp. After that, you will decide your approach, write a computer code and carry out the computations. Finally you will present your results in the final report and in a five-minute presentation to the class.

Topic 1. Development of a Computer Code for Computations of Equilibrium Air Properties

We are asked to start from the partition function to compute equilibrium thermodynamic properties of air as a function of pressure and temperature. We have done a simple case in HW#6. In this case, we will do a more realistic case by assuming that air is a mixture of N_2 and O_2 at low temperature (use approximate mole ratio of 79% to 21%). At high temperature, we can consider the air is a mixture of the following species: N_2, O_2, NO, N, O, N^+, O^+, e. The partition functions of the species except NO can be found in Hansen (1958) uploaded in courseweb. The partition function and dissociation of NO was covered in the lectures. You need to write a computer program to compute h, e, s, c_i, Z, and ρ as functions of p and T. It will be nice if you can compute the speed of sound also. It is up to you to decide how to carry it out and how to present them. You can draw figures similar to those of Figure 1 to Figure 3 of Hansen (1958). You can also draw the results for species concentration similar to Fig 4 on page 174 of Vincenti's book. You can also compare your results with Hansen and other published results.

Initial References:

1. *Chapter 11 of Anderson.*
2. *Chapter 5 of Vincenti and Kruger and the two references by Hansen (1958) uploaded in courseweb.*
3. *Other references cited in Anderson and Vincenti's books.*

Topic 2. Equilibrium Air Flow Across a Hypersonic Shock Waves

Write a computer program to reproduce the strong shock results of Figures 14.4 and 14.5 of Anderson's book. There are many equilibrium air thermodynamic property models. One easy way is to use the equilibrium air model of Tannehill and Mugge (1974) described in Section 11.13 of Anderson's book in the iteration. Since their model uses e and ρ as independent variables, you may need to modify the iteration procedure so that the thermodynamics variables can be calculated easily. Please read the references first and then design your iteration procedure. You will then write a computer code to carry out the calculations.

References:

1. *Chapter 14 of Anderson and Ref [165] by Huber (1963) and Ref [155] by Tannehill et al. (1974)*
2. *Chapter 6 of Vincenti and Kruger and Ref. by Huber, P. W. (1958) on Page 196.*

Topic 3. Equilibrium Air Flow in a High-Temperature Hypersonic Nozzles

Write a computer program to compute the results equilibrium air flow in a high-temperature hypersonic nozzle. You can use the same flow conditions as the following references below. Or you can come up with your own flow conditions and a specific nozzle shape. You then compute the flow properties along the nozzle. Again, you can use the equilibrium air model of Tannehill and Mugge described in Section 11.13 of Anderson's book in the iteration. Since their model uses e and ρ as independent variables, you may need to modify the iteration procedure so that the thermodynamics variables can be calculated easily. Please read the references first and then design your iteration procedure. You will then write a computer code to carry out the calculations. You can plot figures similar to those of Figures 14.13 and 14.14 of Anderson's book.

References:

3. Chapter 14 of Anderson.
4. Chapter 6 of Vincenti and Kruger and Ref. by Erickson (1960) and by Jorgensen (1962).

Topic 4

CFD Computations with the equilibrium air model for Tannehill and Mugge for flow inside a hypersonic inlet with shock reflection. This is for those who have taken my 250D class only. You can start from your perfect gas code developed in the final project of 250D. You then modified the thermodynamic relations by using Tannehill and Mugge's model. You can then compare the results between those of perfect gas and of the equilibrium real gas model.

Topic 5

Develop a computer code for high-temperature wind tunnel design by using the method of characteristics for equilibrium real gas flow inside a rocket engine. You have studied the same problem for perfect gas in MAE 250C. Now you can extend the approach to equilibrium gas flow. You can then compute the results between the perfect and real gas to see how different the wind tunnel shape will be when real gas effects are introduced.

Topic 6

Develop a computer code to compute oblique shock relation for real gas flow and compare your results with those presented in Figure 14.8a of Anderson's book.

Topic 7

Develop a computer code to compute Prandtl-Meyer expansion for equilibrium real gas flow and compare your results with Fig. 6 on page 191 of Vincenti & Kruger's book.

Topic 8

Development and evaluation of analytical curve fit formulas of equilibrium reaction constants K_p.

Topic 9

Computations of self-similar hypersonic boundary layer solution using the perfect gas and equilibrium reacting gas models.

Topic 10

Evaluation of the effects of different nonequilibrium reaction rate constants for an air mixture in an enclosed container with a fixed temperature and density.

Topic 11

Your own big ideas. Need to be related the hypersonic flow and feasible though…